

REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words) A model FIRL-100 far infrared laser system was purchased from Edinburgh Instruments. The FIR laser was installed and tested. In addition, three related experiments were carried out using the new apparatus in order to evaluate the performance under laboratory conditions. These experiments are: A. FIR absorption from an n-type modulation doped GaAs/AlGaAs quantum well structure. The electron cyclotron resonance was recorded for a number of laser lines. B. FIR absorption from an n-type modulation doped InGaAs/InAlAs quantum well structure. The effective mass of the confined electrons was determined. C. Photoluminescence based Optically detected Resonance (PLODR) from an undoped CdMnTe/CdMgTe quantum well structure. In this experiment the excitonic photoluminescence intensity was modulated by the FIR laser. Both electron and hole cyclotron resonances were observed			
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REPORT DOCUMENTATION PAGE (SF298)
(Continuation Sheet)

Statement of the Problem Studied

Contract DAAD19-00-1-0107 is an instrumentation grant for the purchase of two laser systems for the study of semiconductor heterostructures. The first system is a tunable far infrared (FIR) laser pumped by a CO₂ laser manufactured by Edinburgh Instruments. The second item is a continuously tunable pulsed dye laser pumped by a Nitrogen laser, manufactured by Laser Science Inc. A cutback in the budget forced the PIs to drop the second item (pulsed dye laser) and use the available funds towards the purchase of the Edinburgh Instruments FIR laser system. In the following section we describe the various tests that were performed to evaluate the FIR laser. These include three related experiments.

Summary of the Most Important Results

Appropriate electrical and cooling water connections were made in preparation of the new laser system operation and testing. In addition, the elaborate gas handling system necessary for the laser operation was installed. The Edinburgh Instruments FIRL-100 laser was first tested by operating it on its major emission lines for three different gases. These are listed below:

A. Methanol (CH₃OH)

Wavelength (μm)	Photon Energy (meV)
70.5	17.6
96.5	12.8
118.0	10.5
163.0	7.6

B. Difluoromethane (CH₂F₂)

Wavelength (μm)	Photon Energy (meV)
117.7	10.5
184.3	6.7
224.5	5.5

C. Formic Acid (CH₃COOH)

Wavelength (μm)	Photon Energy (meV)
432.0	2.9

Below we describe the results of the first experiments carried out on semiconductor heterostructures using this FIR laser system.

Sample 1. N-type modulation doped GaAs/AlGaAs quantum well structure (electron density $n = 1.5 \times 10^{11} \text{ cm}^{-2}$)

In fig.1 we show four absorption spectra taken with different laser lines by ramping an externally applied magnetic field along the normal to the sample layers. The sharp features in fig.1 are attributed to electron cyclotron resonance of the confined quasi two dimensional electron gas. In fig.2 we plot the FIR photon energy as function of the resonant magnetic field. The experimental points yield a straight line that correspond to an electron effective mass $m^* = 0.0665$

Sample 2. N-type modulation doped InGaAs/InAlAs quantum well structure (electron density $n = 3 \times 10^{12} \text{ cm}^{-2}$)

In fig.3 we give a similar series of absorption spectra for sample 2. The features in the spectra of fig.3 are attributed to electron cyclotron resonance. The broadening of the resonances of sample 2 compared to those of sample 1 is due to two factors:

- a. The well material in sample 2 (InGaAs) is an alloy and the resulting composition fluctuations contribute to the increase of the resonance linewidth.
- b. The carrier concentration in sample 2 is more than an order of magnitude higher than in sample 1. Stronger electron-electron interactions in sample 2 tend to increase the linewidth of the electron cyclotron resonance

The summary plot for this sample is given in fig.4. The electron effective mass $m^* = 0.0565$

Sample 3 CdMnTe/CdMgTe quantum well structure, undoped

A series of photoluminescence optically detected resonance (PLODR) experiments were carried out on sample 3. The PL was excited using the 488 nm line from an argon-ion laser. The sample was also illuminated by the 184.3 μm line of the FIR laser (using CH_2F_2 as the lasing gas). The exciton PL feature intensity was monitored using a grating spectrometer equipped with a photomultiplier tube. Changes in the PL signal level induced by the FIR photons were recorded as function of the externally applied magnetic field. At magnetic field values for which the FIR photon energy matched one of the resonances of the system under study a large change in the PL intensity was observed. A PLODR scan for sample 3 is shown in fig.5. Two resonances are observed ;one at 6 T (feature A) and a second at 12 T (feature B). Feature A is identified as the electron cyclotron resonance (electron effective mass $m^* = 0.096$). Feature B is associated with the heavy hole ($m_h = \pm 3/2$) cyclotron resonance.

Sample 3 is a member of a series of CdMnTe/CdMgTe heterostructures. Systematic work on this series is currently under way. A report on the results of this effort will be presented at the 2002 March Meeting of the American Physical Society.

Sample 1

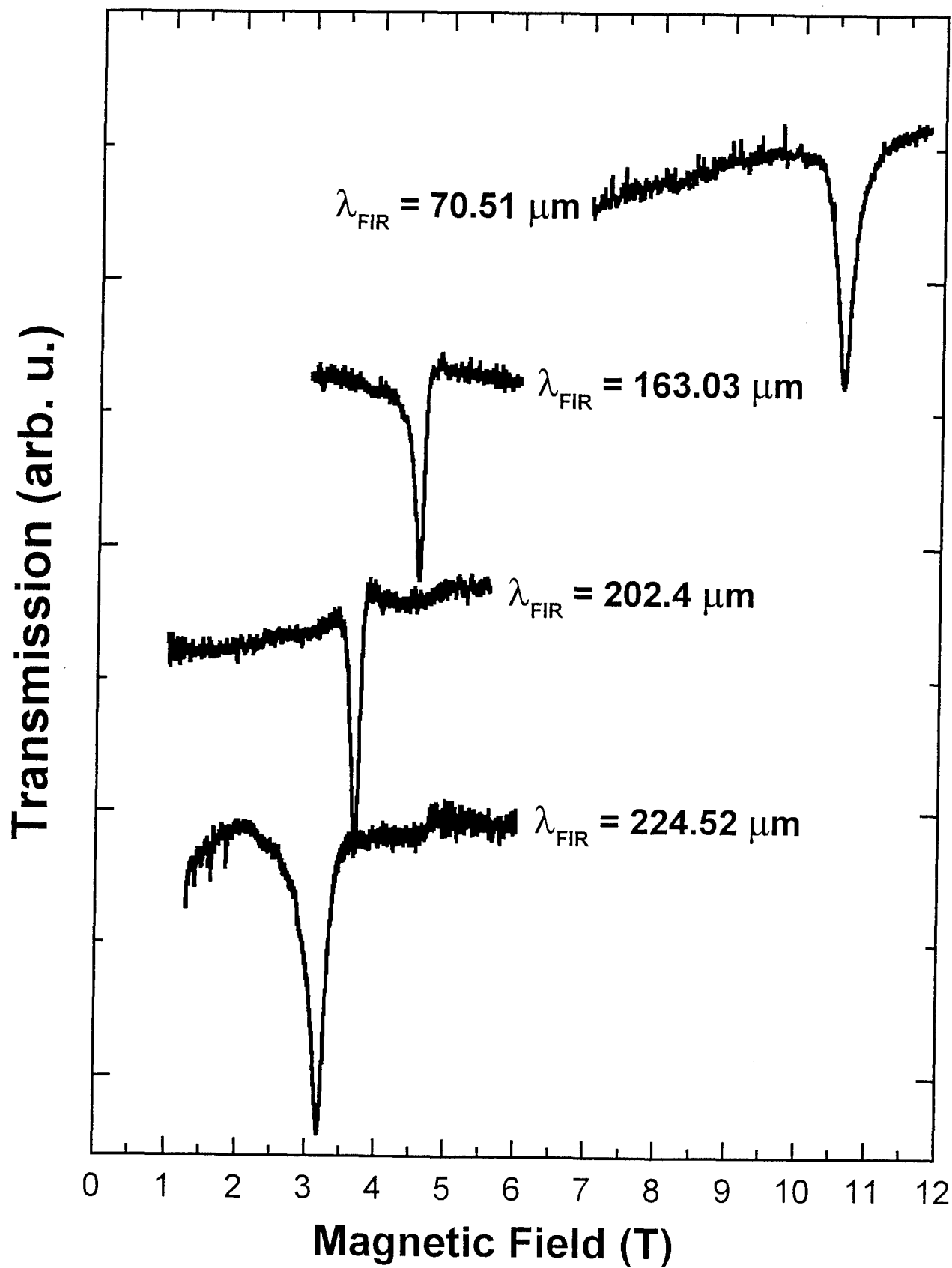


Fig.1

Sample 1

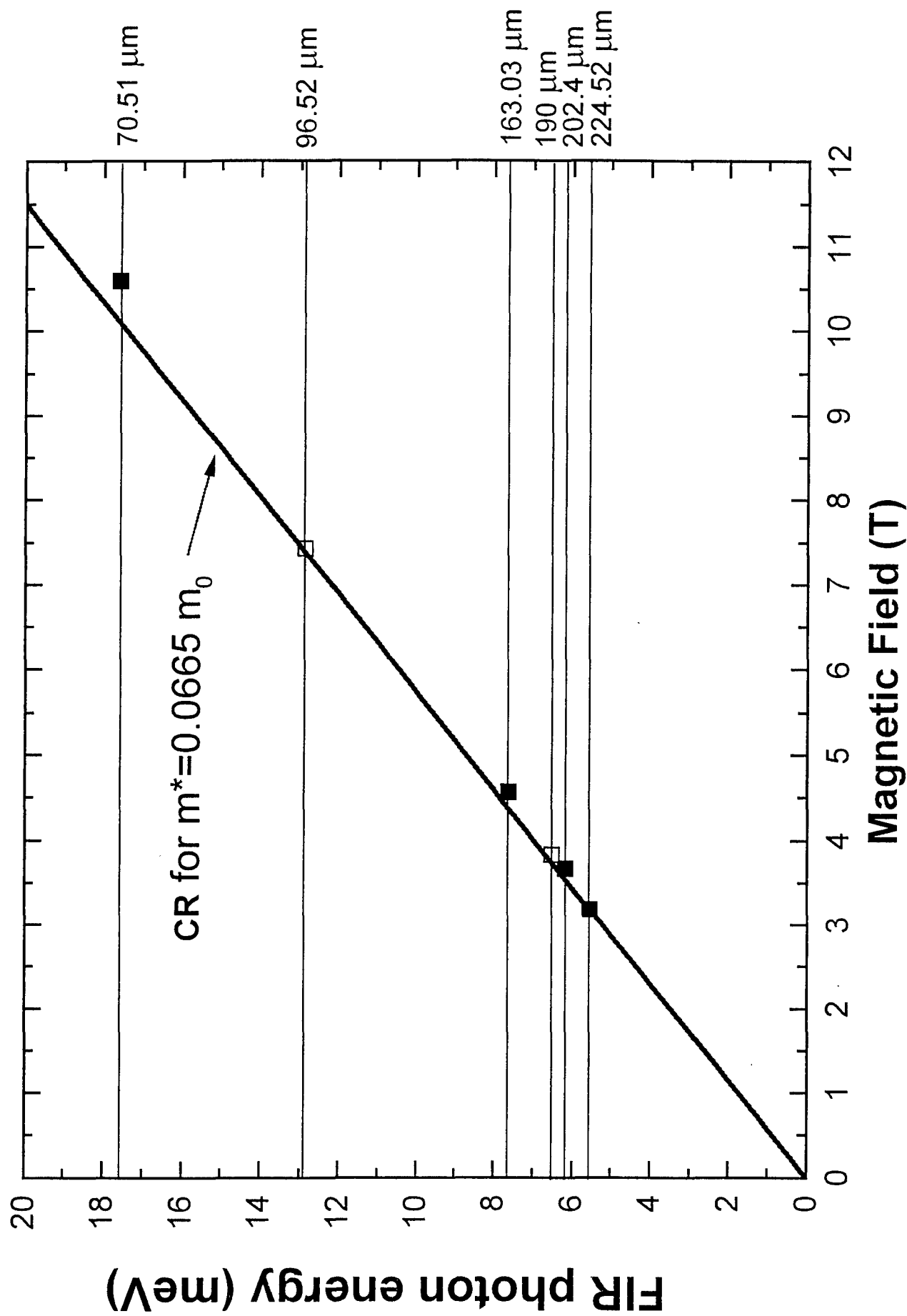


Fig.2

Sample 2

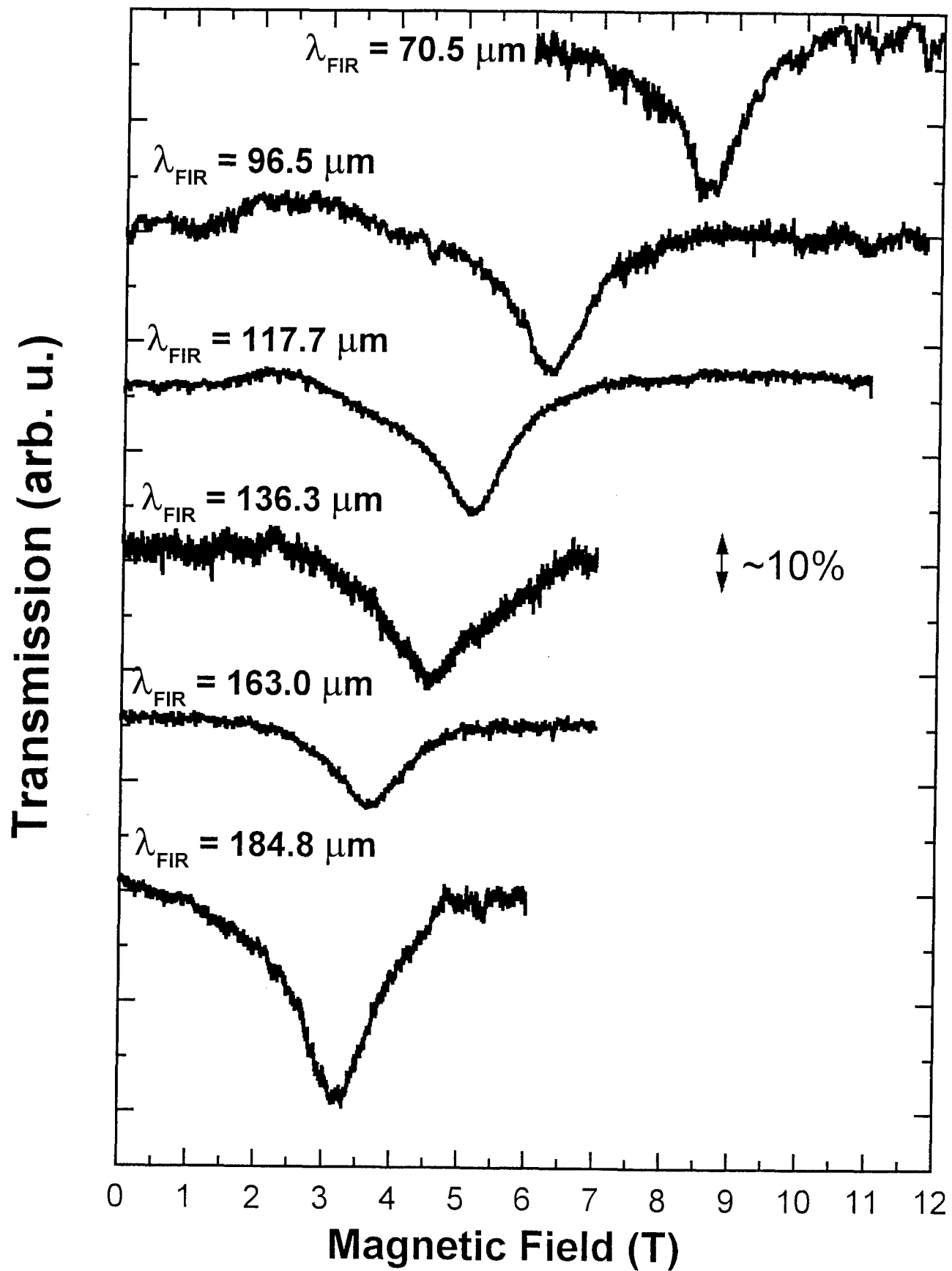


Fig.3

Sample 2

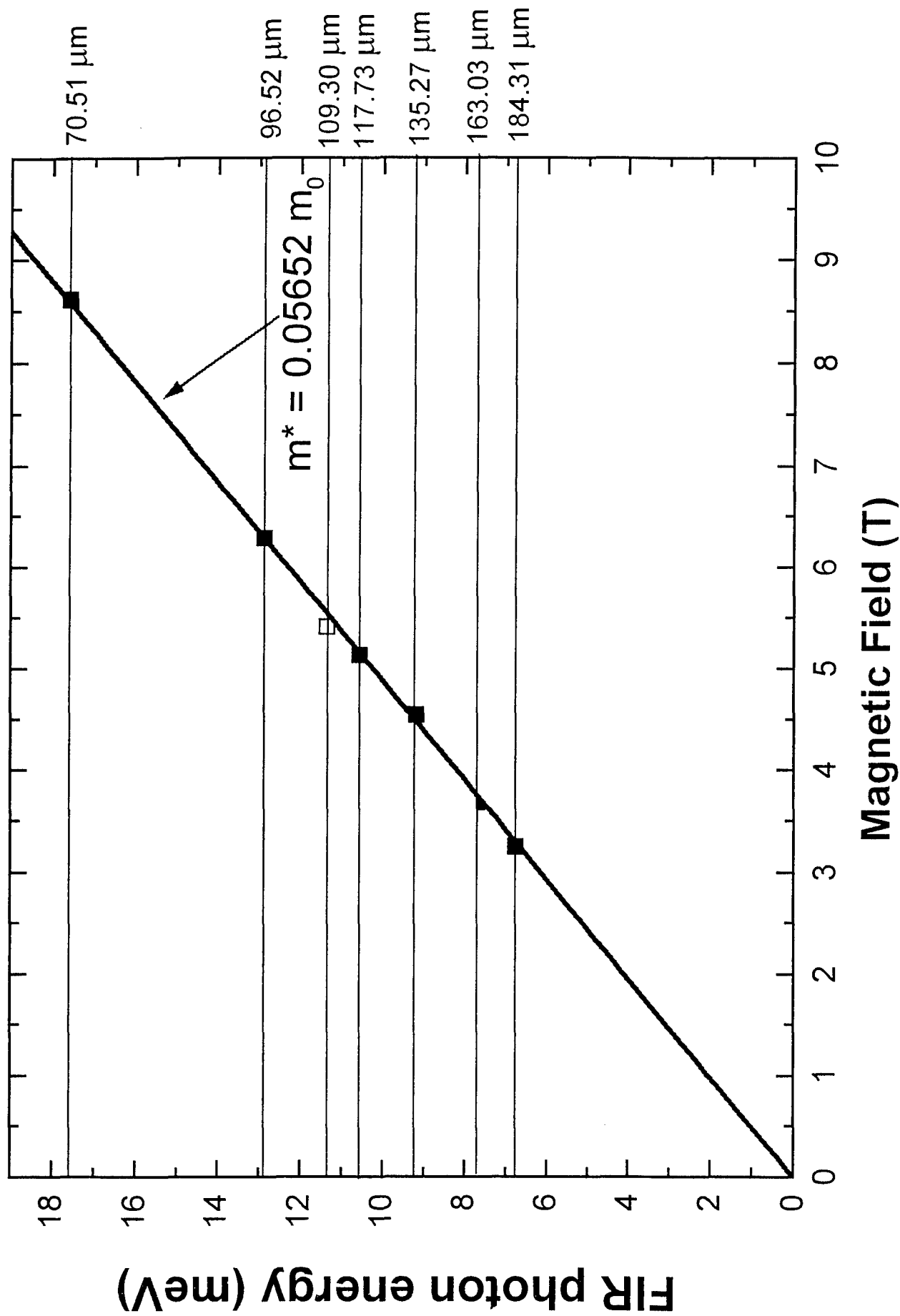


Fig.4

Sample 3

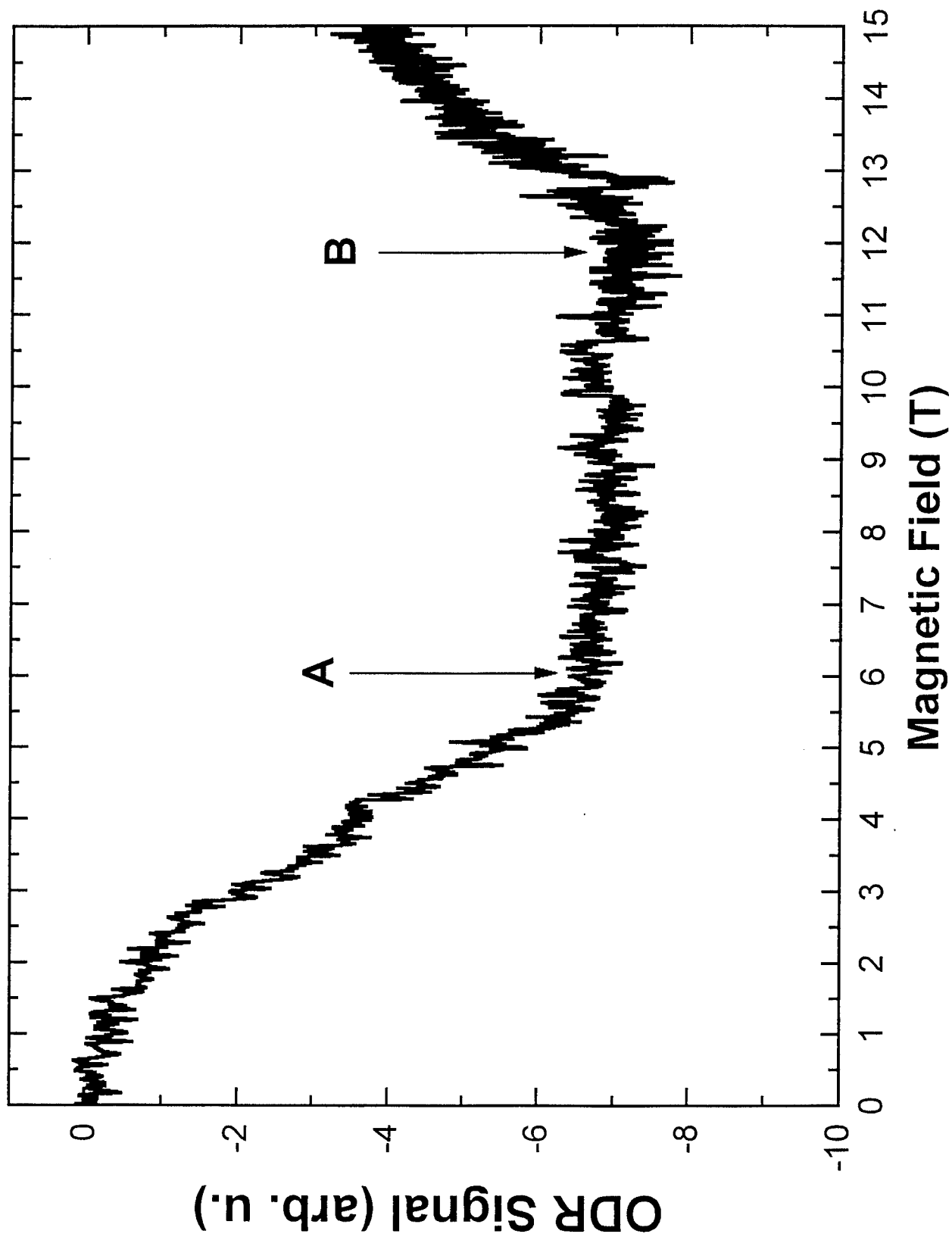


Fig.5